The Effects of a 5-week Technologically-Enhanced Cognitive-Motor Dual-Task Training Program on the Cognitive Functions of a Healthy 70-year-old female.

Dual-tasking is the concurrent performance of two tasks that can be performed independently and have distinct and separate goals. Dual-tasking has many real-world applications and is one cognitive ability that tends to deteriorate with age. In fact, a reduced ability to simultaneously divide attention between tasks (dual-tasking) has been linked to reduced reaction time and walking speed, more frequent run-ins with obstacles and an increased risk of falls [1]. Inability to successfully dual-task also creates dangerous conditions when driving. [2]

Preliminary research suggests that engaging in cognitive-motor and dual-task training simultaneously may be more beneficial than merely the sum of their separate gains and that their combined effects can have a profound impact on both ameliorating and preventing cognitive decline in older individuals.

Dual-tasking during aerobic exercise and cognitive challenges is a recently emerging and promising area of research. While cognitive exercise and physical exercise has unique benefits on the body and brain, several benefits are shared between the two. The primary micro-level mechanisms are thought to be neurogenesis, synaptogenesis, and increased cerebral blood flow, while functional changes to neural circuits specific to cognitive inputs are thought to be activated. Preliminary research in both animals and humans suggests that the simultaneous activation of these benefits may be larger than the additive properties of doing the two exercises sequentially or separately. [3]

While there is debate about what modality or type of exercise yields the most cognitive benefits, it is likely that each modality offers unique cognitive benefits, and that combining them might glean a share of these cognitive benefits. Interventions using at Multicomponent Training (MCT) which consists of focusing on neuromuscular coordination, balance, agility, and cognitive executive control have been found to have a profound impact on improving inhibition and executive functioning in an older populations.[4]

A systematic review of all current studies examining the effects of motor and cognitive dual-tasking to prevent or slow the age-related decline in cognition found that either simultaneous or subsequent combined cognitive-physical training was more successful when compared with singular interventions alone. There is clear evidence that there are effective training interventions using cognitive-physical dual-tasking, provided the interventions and tests are properly designed.[5]

In addition to the ability for combined cognitive and physical training interventions to improve cognition in those with and those without MCI [6], there exists a desire to target specific cognitive domains in hopes of improving them, something that has been explored in computerized cognitive training literature, but an area that requires more research when discussing cognitive motor dual-tasking.

One such study observed the effects of cognitive motor dual-tasking in a population of healthy older adults, measuring their cognition and blood plasma levels of amyloid-beta, a protein indicative of neurodegenerative disease, specifically Alzheimer's Disease. The dual-task intervention was delivered 3 times per week, for 12 weeks, in a group setting, and similar to other studies, found greater improvements in cognition in the dual-tasking group when compared to a standard training group performing multicomponent exercise.

Additionally, it was observed that verbal fluency improved as a part of increased executive functioning from the intervention, but visual processing speed did not improve. The researchers of this paper discuss that verbal fluency is demanded during group dual-tasking exercise, but since they did not have any techniques requiring the rapid processing of visual input, that specific cognitive domain did not improve, although other dual-task studies have demonstrated such improvements [7].

In order to test this theory of domain targeted cognitive motor dual-tasking and its effectiveness at improving specific domains of cognition, a single case study of a healthy, trained, 70-year-old woman underwent a customized cognitive motor dual-task training program. The SMARTfit Mini System, a touch-based multi-target system that displays cognitive tasks that are engaged during simultaneous movements, was utilized for this case study. The subject had reportedly been training on the SMARTfit system for 15 months on an average of 3 times per week, and baseline cognitive testing prior to the SMARTfit intervention was not given.

To assess the subject's current cognitive status, a 12-task battery was administered electronically by Cambridge Brain Sciences (CBS). The CBS battery consists of cognitive tasks that address the domains of memory, concentration, reasoning, and planning, all of which have been correlated highly with measures of generalized fluid intelligence [8]. The CBS platform generates random version of each task so as to minimize practice effects, and has demonstrated effectiveness in large-scale studies of population-level cognition [9]. The CBS platform automatically determine if there is a statistically significant change across different time points of testing. The specific age norms for comparison of this case study subject was 65-74, and the gender of the norms for comparison was female.

The CBS test was administered as a baseline, and specific domains of cognition that were measured as low or low-average were highlighted. Other domains of cognition that the CBS test found to be average or high-average were considered, but not prioritized. The highlighted cognitive domains of low or low-average were selected as targets for improvement after the first baseline CBS test (Figures 1-4), and various SMARTfit tasks were selected to theoretically address each of these highlighted domains of cognition. An analysis of the current SMARTfit cognitive motor training program was implemented to assess what SMARTfit cognitive tasks were being selected, what movements were performed during these tasks, and for how long.

The SMARTfit cognitive-motor training intervention consisted of selecting activities the address visuospatial working memory, impulse control, and planning. These types of activities included hitting targets with either the left, right or both hands according to a visual cue, finding a smiley face hidden among other non-smiling emojis, matching complex shapes using short-term memory, and hitting one target while searching and inhibiting hitting other false targets.

While these tasks were being engaged, complex movements, such as alternating lateral lunges, single leg reaches with balancing, cardiovascular stepping, and gross motor patterns using balance implements and weights were implemented simultaneously. Compared to the previously executed exercise program, more complex lower exercises where given in place of static balance exercises. Several sets of exercises were performed at various lengths, ranging from 2 minutes to 4 minutes. This intervention was carried out for an average of 45 minutes per session, 5 times per week, for 5 weeks. CBS testing was administered before the 5 week intervention, and at weekly time points, with the final time point being administered after 2 weeks of no training.

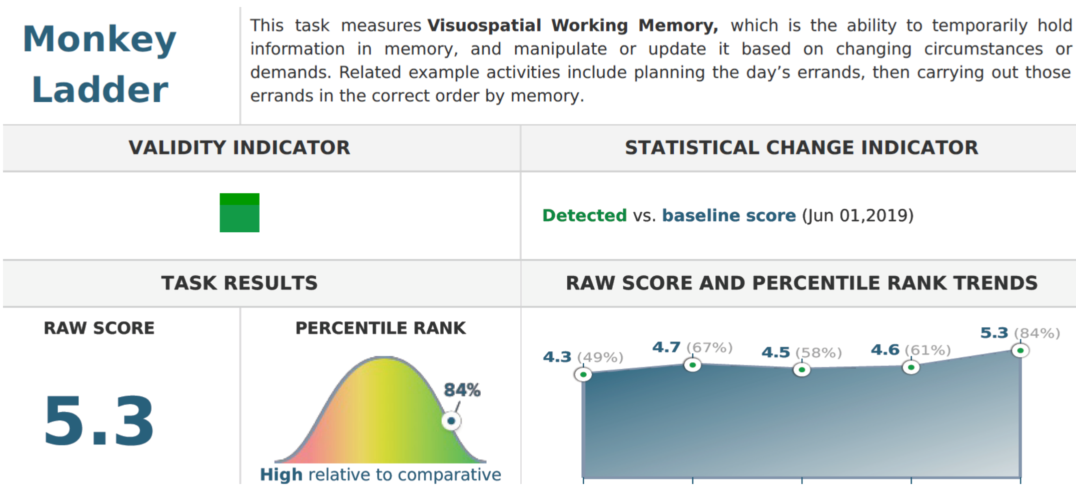
The results of the CBS test after the SMARTfit cognitive motor training intervention included significant improvements in visuospatial working memory, planning, mental rotation and impulse control. Improvements, although not statistically significant, were found in spatial short-term memory, working memory, verbal reasoning, and verbal short-term memory. No changes were found in attention, episodic memory, visuospatial processing, and deductive reasoning.

Overall, it was surprising to find that a subject experienced in SMARTfit cognitive motor training was able to improve cognitive abilities when selecting specific domains of cognition in which she was less proficient, and targeting them with specific tasks. It is worth noting that the accommodating exercise program was made more coordinatively complex and physically challenging, the length of sets was increased, and variability within SMARTfit tasks was applied.

The potential rationale for these improvements may certainly rely within the efficacy of targeting different domains of cognition, especially in visuospatial working memory, inhibition and planning. The SMARTfit cognitive motor training intervention that was designed demanded these specific functions, which may explain why they improved. It is also worth noting that the subject was highly motivated, which, when combined with constantly challenging scenarios relative to individual skill level and a degree of emotional enjoyment, are more likely to improve different aspects of executive functions better than interventions that do not. [10]

More research in domain specific cognitive motor training programs is needed, but encouraging prior evidence for such interventions, combined with the results from the case study, could provide a framework for assessing and designing cognitive domain-specific dual-tasking interventions to enhance brain health, specific cognitive abilities and physical function.

Figures 1-4: Domains of Cognition Where Significant Change Was Detected



Rotations

This task measures **Mental Rotation,** which is the ability to efficiently manipulate mental representations of objects in order to make valid conclusions about what objects are and where they belong. Related example activities include finding the route to a room inside a building even though you came in through a different door when you first learned your way around.

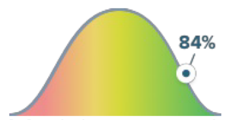
VALIDITY INDICATOR	STATISTICAL CHANGE INDICATOR
	NOT DETECTED

TASK RESULTS

RAW SCORE

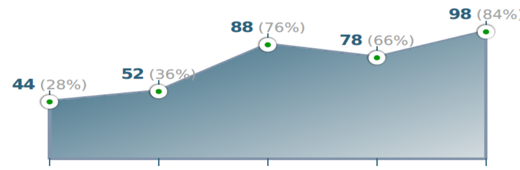
98

PERCENTILE RANK



High relative to comparative

RAW SCORE AND PERCENTILE RANK TRENDS



Double Trouble

This task measures **Response Inhibition,** which is the ability to concentrate on relevant information in order to make a correct response despite interference or distracting information. Related example activities include blocking out background conversations when you're trying to focus on something, or ignoring buzz words when viewing a television ad and focusing your attention on more important factors, like the price and quality of the item being sold.

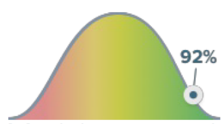
VALIDITY INDICATOR	STATISTICAL CHANGE INDICATOR
	Detected vs. **baseline score** (Jun 01,2019)

TASK RESULTS

RAW SCORE

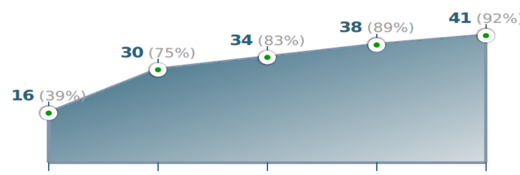
41

PERCENTILE RANK



High relative to comparative

RAW SCORE AND PERCENTILE RANK TRENDS



Spatial Planning

This task measures **Planning,** which is the ability to act with forethought and sequence behaviour in an orderly fashion to reach specific goals. Related example activities include packing items into your car's trunk so that they all fit, or assembling a piece of furniture.

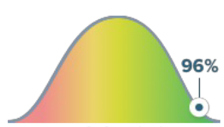
VALIDITY INDICATOR	STATISTICAL CHANGE INDICATOR
	Detected vs. **previous valid score** (Jul 14,2019)

TASK RESULTS

RAW SCORE

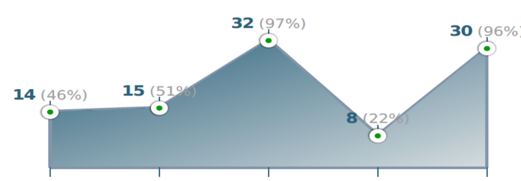
30

PERCENTILE RANK



Very High relative to

RAW SCORE AND PERCENTILE RANK TRENDS



Citations

[1] Melzer, I., Kurz, I., & Oddsson, L. I. (2010). A retrospective analysis of balance control parameters in elderly fallers and non-fallers. *Clinical Biomechanics*, *25*(10), 984-988.

Pichierri, G., Wolf, P., Murer, K., & de Bruin, E. D. (2011). Cognitive and cognitive-motor interventions affecting physical functioning: a systematic review. *BMC geriatrics*, *11*(1), 29

[2] Anstey, K. J., Wood, J., Lord, S., & Walker, J. G. (2005). Cognitive, sensory and physical factors enabling driving safety in older adults. *Clinical Psychology Review*, *25*(1), 45 -65. https://doi.org/10.1016/j.cpr.2004.07.008

[3] McEwen, S. C., Siddarth, P., Abdel Sater, B., Kim, Y., Mui, W., Wu, P., … Merrill, D. A. (2018). Simultaneous Aerobic Exercise and Memory Training Program in Older Adults with Subjective Memory Impairments. *Journal of Alzheimer's Disease: JAD*, *62*(2), 795–806. https://doi.org/10.3233/JAD-170846

[4] Forte, R., Boreham, C. A., Leite, J. C., De Vito, G., Brennan, L., Gibney, E. R., & Pesce, C. (2013). Enhancing cognitive functioning in the elderly: multicomponent vs resistance training. *Clinical Interventions in Aging*, *8*, 19–27. https://doi.org/10.2147/CIA.S36514

[5] Lauenroth, A., Ioannidis, A. E., & Teichmann, B. (2016). Influence of combined physical and cognitive training on cognition: a systematic review. *BMC Geriatrics*, *16*(1), 141. https://doi.org/10.1186/s12877-016-0315-1

[6] Law, L. L., Barnett, F., Yau, M. K., & Gray, M. A. (2014). Effects of combined cognitive and exercise interventions on cognition in older adults with and without cognitive impairment: a systematic review. *Ageing research reviews*, *15*, 61-75.

[7] Yokoyama, H., Okazaki, K., Imai, D., Yamashina, Y., Takeda, R., Naghavi, N., ... & Miyagawa, T. (2015). The effect of cognitive-motor dual-task training on cognitive function and plasma amyloid β peptide 42/40 ratio in healthy elderly persons: a randomized controlled trial. *BMC geriatrics*, *15*(1), 60.

[8] Gray, J. R., Chabris, C. F., & Braver, T. S. (2003). Neural mechanisms of general fluid intelligence. *Nature neuroscience*, *6*(3), 316.

[9] Silva, N. C. B. S., Gill, D. P., Owen, A. M., Liu-Ambrose, T., Hachinski, V., Shigematsu, R., & Petrella, R. J. (2018). Cognitive changes following multiple-modality exercise and mind-motor training in older adults with subjective cognitive complaints: The M4 study. *PloS one*, *13*(4), e0196356.

[10] Diamond, A., & Ling, D. S. (2016). Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. *Developmental cognitive neuroscience*, *18*, 34-48.